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Probing the monsoon pulse

Identification of long-term changes in periods of extreme heavy and weak rainfall during the Indian monsoon season has been elusive. Now, an observational study provides the firmest evidence so far.

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The recent floods over northern India during June 2013 reminded us vividly of the vital socio-economic importance of extreme variability of the South Asian summer monsoon. Given the devastating impact of severe rainfall events on human society and the environment, whether their characteristics underwent changes in the recent past is an issue of utmost importance[1]. Additionally, this is critical for more reliable projections of future changes[2] and to effectively manage future climate-related risks[3]. However, long-term changes in the total precipitation during the monsoon season have received considerably more attention, and existing studies on subseasonal variability have shown rather contradictory results[4,5]. In a study published in *Nature Climate Change*, Deepti Singh and colleagues [6] use a rigorous statistical approach to identify robust changes in the observed frequency and intensity of monsoon extreme rainfall spells during the last 60 years.

The June-September monsoon season provides up to 80% of the total annual rainfall over the Indian subcontinent, where more than 1.7 billion people (over 25% of the world's population) live and strongly rely on monsoon rainfall for their mainly agrarian societies. Rather surprisingly, seasonal mean rainfall is remarkably stable from year to year, with variations typically within 10% of the long-term mean[3,5,7]. However, once the monsoon is underway, rainfall is not steady but is punctuated by considerable fluctuations between days-to-weeks-long periods of heavy and low rainfall (wet and dry spells)[5,6]. Extremes in these events, which manifest as floods and droughts, have tremendous impacts on agriculture, health, economy, and water supply[1]. The prolonged monsoon failure during July 2002, with a 50% rainfall deficit, contributed to a remarkable reduction in agricultural production and gross domestic product growth rate.

Singh et al.[6] move beyond previous works by conducting a robust statistical analysis on daily precipitation observations and accounting for a number of sources of uncertainties in the methodology. This work shows compelling evidence of changes in the characteristics of peak monsoon (July-August) extreme spells since the mid-20th century. Using rainfall anomalies averaged over the representative core monsoon region over central India, extreme wet and dry spells are formally defined as periods of three of more consecutive days with anomalies exceeding the long-term mean variability (one standard deviation).

On top of reduced seasonal mean precipitation since the 1950s[8], daily rainfall variability increased, as a result of rain occurring less frequently but with more variable intensity. This, for example, leads to an increased frequency of both light and heavy rainfall events, consistently with an earlier study[4], and a 2 mm perday reduction of the most likely daily amount. Singh et al.[6] also show a statistically significant shift toward more intense wet spells, and more frequent but less intense dry spells. Though the frequency of wet spells shows a decreasing trend over the last few decades, consistent with the decreasing number of monsoon depressions over the Bay of Bengal, the number and duration of events do not change significantly over the whole period. Similarly, the duration and cumulative length of dry spells show increasing trends, though their weak magnitudes prevent them from being unambiguously isolated. These changes are supported by an increased amount of available energy and convergence of moisture over the region, two conditions favouring stronger convective activity. Recognising that their analysis might be potentially hampered by arbitrary choices in the methodology, Singh et al.[6] test the robustness of their findings against the choice of a second precipitation dataset, the size of the core monsoon region, and the length of the two sample periods used to build the statistics.

Much is yet to be done, however, to extend our understanding. While focusing mostly on rainfall, arguably the most important feature of the monsoon, Singh et al.[6] did not fully investigate the physical mechanisms associated with the extreme spells. These include for example a characterization of their evolution, transitions, and links with the coupled land-atmosphere-ocean monsoon system[5]. Steps into this direction will improve the understanding of the temporal and spatial nature of the spells. This requires accounting also for multi-scale interactions in the monsoon over the entire season[7] whereby, for example, subseasonal variability is not completely separable from the underlying changes at seasonal and interannual timescales[3].

Additional compelling, but currently unanswered, questions are whether (and to what extent) long-term changes in the monsoon spells could be associated and possibly attributed to human factors, such as greenhouse gases or aerosols emissions. This directly relates to the root cause of the changes. Human-induced warming is expected to lead to an increase in heavy rainfall events due to enhanced moisture content in the atmosphere, with less frequent and/or less intense weak precipitation events[3,4]. Evidence shown by Singh et al.[6] and previous studies is partially consistent with this picture. Increased aerosols have also been suggested to affect seasonal and sub-seasonal monsoon precipitation[8], including potentially the transition from dry to wet spells[9]. Although global climate models are still fraught with uncertainties, especially with regard to simulating the monsoon subseasonal variability[3], they hold the key to address these issues, and to increase our ability to predict and interpret future regional climate change. Some results seem promising[2], and the higher spatial resolution of the newest models is expected to reduce current uncertainties.

Despite some limitations, the findings of Singh et al.[6] represent a further step toward a rigorous identification of recent long-term changes in the South Asian monsoon variability and a reference for future studies. Extreme rainfall results in landslides, floods, and crop damage that have major impacts on society, the economy, and the environment[1]. This study provides important information for water resources, agriculture, disaster preparedness, and infrastructure planning.

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Figure caption:
During the South Asian summer monsoon season rainfall fluctuates between wet and dry spells, which are periods of heavy and weak rainfall. Extreme spells have large impacts on economy and livelihood over the Indian subcontinent, such as the case of prolonged dry spells during critical growth periods of agricultural crops. Singh et al.[6] analyse daily rainfall observations over India to identify possible changes in the characteristics of dry and wet spells that may have occurred since the middle of the 20th century. They find robust evidence of wet spells becoming more intense, that is pouring more rain in a given number of days, and of dry spells getting more frequent but less intense.